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Chapter

Practical Approach to Chest Pain Related to Cardiac Implantable Electronic Device Implantation

Umashankar Lakshmanadoss, Imran Sulemankhil and Karnika Senthilkumar

Abstract

In this review article, we described the common causes and approach for chest pain that happens after cardiac device implantation surgeries. We also describe the clinical features and appropriate treatment for them.

Keywords: CIED implant, chest pain, pericardial effusion, pneumothorax, erosion of device

1. Introduction

Cardiac implantable electronic devices (CIED) are being implanted for more than 600,000 patients on a yearly basis [1]. These CIEDs include pacemakers, implantable cardioverter defibrillators, and cardiac resynchronization therapy devices [2]. These implantation surgeries are not without risk, as there are many potential complications that can occur either immediately or in a delayed setting [3–6]. Many of the complications could have a common presentation of chest pain, and depending on the etiology, morbidity, and mortality can vary widely [7]. The surgical process itself during the cardiac implantation device surgery can result in chest pain [8]. However, it is paramount to differentiate chest pain due to acute coronary syndrome (ACS) from non-ischemic causes. In the setting of a ventricular paced rhythm or left bundle branch block, this can be difficult with electrocardiography as the ST segments or T waves may hide or mimic ACS [9]. In this situation, the modified Sgarbossa criteria can be implemented to improve the diagnostic accuracy of electrocardiography in this patient population [10–12]. Hence, it is very important to identify the causes of chest pain after any cardiac implantation device surgery. In this chapter, we will discuss a practical approach to chest pain after cardiac implantation device surgery.

2. Chest pain after CIED implantation

For practical purposes, the etiology of chest pain after device implantation surgery could be divided based on the time of occurrence. We classified it into the following three categories:

1. Immediate chest pain (during the procedure)

2. Post procedural chest pain (in the immediate postoperative period, within 1–2 days)

3. Delayed chest pain

Just like any other surgical process, placing the leads and the devices resulted in various forms of trauma and by itself can produce chest pain. These adverse effects can occur during the procedure, in the immediate postoperative period, and well after the implant procedure.

2.1 Immediate chest pain during the procedure

2.1.1 Musculoskeletal

Most of these CIED surgeries are performed with moderate sedation [13]. Patients who undergo CIED surgeries are commonly elderly and have multiple co-morbid conditions [14]. This clearly limits the options for adequate analgesia and sedation due to concerns for adverse effects of sedatives and analgesics. Hence, adequate local anesthesia plays a major role in terms of pain control. If the patients are not adequately anesthetized with local anesthesia, they may experience sharp pain during various parts of device implantation. Even if they are adequately anesthetized with local anesthesia, this will be effective predominantly within the subcutaneous tissue [15]. Furthermore, patients may feel sharp pain when the muscle tissue is being manipulated, especially if they have to have a suture or cauterization of the muscles secondary to inadvertent bleeding. Safe vascular access is very important to minimize the complications of CIED surgery. Hence, most of the operating physicians try to use the junction between the clavicle and first rib as a landmark to minimize the risk of pneumothorax. Typically, the axillary vein can be accessed just at the level of the first rib [16]. If the needle passes the veins "through and through" and hits the periosteum of the first rib, patients may feel this discomfort. After venous access, when the sheath is being advanced into the venous system, it could stretch the periosteum of the costoclavicular ligament which in turn can be uncomfortable for the patient. Hence, during this part of the procedure, it is very important to provide appropriate analgesia for the patient.

2.1.2 Pneumothorax

Pneumothorax, hemothorax, and hydropneumothorax are some of the dangerous complications after CIED implantation [17]. Implanting-physicians always strive to minimize these complications as they increase the morbidity and mortality. These complications are reduced by using micropuncture access needles, using contrast venography to identify the veins, and using ultrasound to identify the veins [18–20]. In addition to this, some physicians also use a bolus of intravenous fluid to engorge veins. Similarly, Trendelenburg positioning or elevating the patient's legs with a wedge under the leg (without tilting the operating table) could be useful [21]. Some physicians also inject contrast when they are gaining access because the contrast tends to engorge the veins. In spite of these careful and meticulous approaches, sometimes pneumothorax is inevitable. Even though, the vein is accessed via the extrathoracic veins, it is possible that the patients may have a small bleb secondary to COPD, which through inadvertent entry may produce a pneumothorax [22]. Pneumothorax could be suspected at the earliest, when there is

aspiration of air with the introducer needle, before entering into the venous system. It is also imperative to note that the needle should be attached to the syringe air tight. Otherwise, it could give a false opinion of aspiration of air into the syringe. During access, after entering into the vein, if the patient has obstructive sleep apnea, they could create huge negative intrathoracic pressure during deep inspiration which in turn can suck in air (**Figure 1**).

Causes of pneumothorax:

1. Advancing the needle deep into the lung parenchyma, beyond the first rib
2. Accidental puncture of superficial blebs
3. Medial puncture (intrathoracic part of the subclavian vein)

If the operating physician noted any signs of aspiration of air into the syringe, then the patient should be carefully monitored for possible pneumothorax. In addition to this, patients may also develop sudden onset of chest pain, cough, hypoxia or tachycardia. During this situation, fluoroscopy can be implemented immediately to evaluate for any pneumothorax; keeping in mind that supine positioning is not the ideal method of assessing for pneumothorax.

2.1.3 Mediastinal bleed

Any mediastinal bleed during CIED implantation could produce acute chest pain. This pain is typically very diffuse and radiates toward the posterior aspect of the chest secondary to mediastinal reflection [23, 24]. Patients may manifest tachycardia secondary to sympathetic stimulation and hypotension, depending upon the extent of the blood loss. This is one of the dangerous conditions, which needs to be identified and addressed as soon as possible. Inadvertent access of the subclavian artery could produce mediastinal bleed. Hence, accessing the axillary vein at the

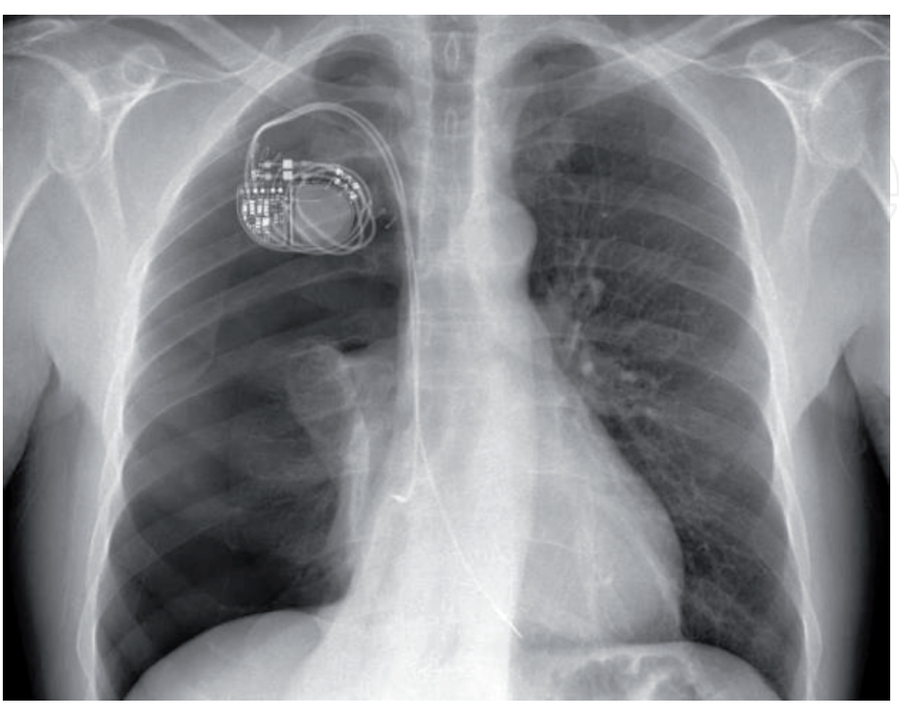

Figure 1.
Chest X-ray showing right sided pneumothorax.

level of the first rib is a preferred approach as it allows for manual compression in this situation [25, 26]. After getting access into the central system, it is very important to advance the guide wire below the diaphragm to confirm placement within the inferior vena cava and not in the arterial side prior to introduction of the sheath. This way, even if there is any inadvertent arterial access, the chances of mediastinal bleeding will be minimized. In the elderly patients, the venous system could be very tortuous especially at the level of the brachiocephalic system [27–29]. Hence, the wire and the sheath have to be advanced very carefully. If there is any resistance noted during advancement of the sheath, further advancement has to be done under fluoroscopic guidance.

2.1.4 Pericardial effusion/tamponade

During device implantation, it is possible that patients may have an acute pericardial bleed leading to either pericardial effusion or pericardial tamponade [17]. Typically, patients have chest pain, tachycardia, and clinical features consistent with cardiogenic shock [30]. Pericardial chest pain typically radiates toward the shoulder blades and also toward the trapezius muscle, at the nape of the neck, due to the pericardial reflection. Further, it may be pleuritic in nature due to rubbing of the pericardium with the pleura [31]. When there is a clinical suspicion for pericardial effusion or pericardial tamponade, immediate imaging is required without any delay; this needs to be addressed immediately, as appropriate treatment is lifesaving. Perforation at the level of the intra-pericardial superior vena cava, right atrium, right atrial appendage, coronary sinus, or right ventricle are all possible and can lead to pericardial effusion [32, 33]. If there is any suspicion of pericardial effusion, immediate fluoroscopic evaluation looking for the lateral movement of the pericardium is useful. Imaging with transthoracic echocardiogram or intracardiac echocardiogram is also of great benefit. Immediate pericardiocentesis will be lifesaving [34]. It is also possible that there may be a slow and progressively worsening pleural effusion, which may not produce any clinical symptoms immediately and patients may present with late pericardial effusion. Minimal or small pericardial effusion could be managed conservatively by following the patient very closely. High dose aspirin, colchicine, and oral corticosteroids can be used to minimize the inflammatory response [31]. However, if there is any hemodynamic compromise, pericardiocentesis is then indicated. Depending on the clinical situation, lead revision may also be indicated (**Figure 2**).

2.2 Intermediate chest pain, during the recovery and within 1–2 days

2.2.1 Surgical site pain

As in any surgical procedure, the most common reason for the pain is usually due to postoperative swelling and will typically respond to simple analgesics and cold compression. In addition to this, it could be due to mechanical reasons including superficial placement of the device within the subcutaneous tissue leading to too much pressure on the skin, lateral device placement in the infraclavicular region leading to mechanical irritation of the axillary nerve, nerve entrapment, etc. [35–37]. Very rarely, patients can also develop allergic reactions to the components of the CIED including titanium, cadmium, chromium, and nickel [38–40]. As these patients are typically advised to use an arm sling, their arm movements can be completely restricted which in turn could lead to shoulder pain [41, 42]; this is similar to early phase of adhesive capsulitis.

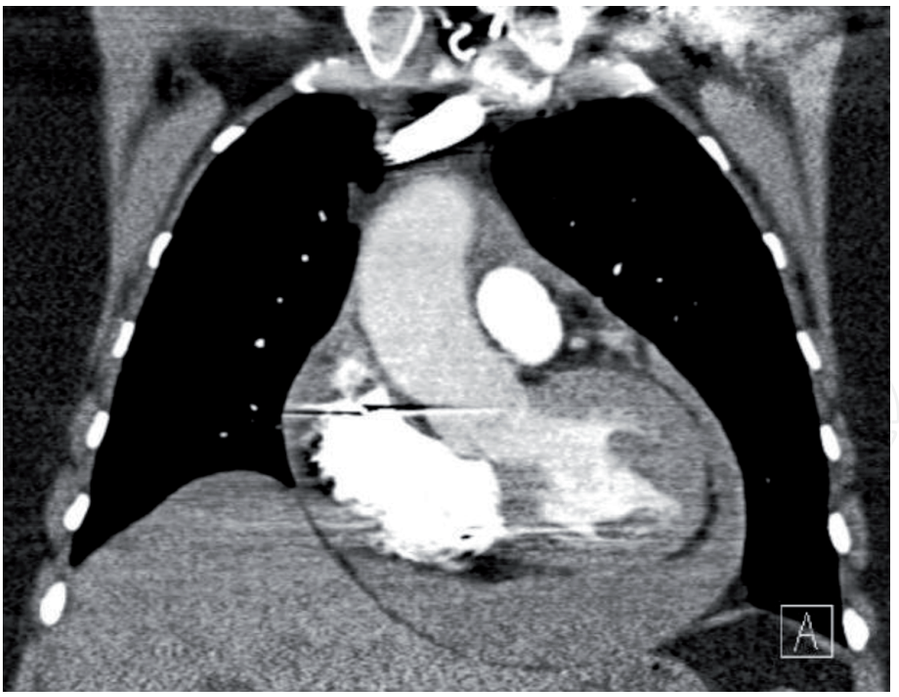

Figure 2.
CT chest showing pericardial effusion.

2.2.2 Pleuritic/pericardial involvement

As discussed above, pneumothorax, pneumopericardium, hydropneumothorax, and pericardial effusion can produce delayed symptoms of pleural or pericardial pain leading to chest pain. This is typically due to a break in the continuity of the pleural or pericardial membrane secondary to lead perforation. It could be secondary to micro or macro perforations [43–45]. Nevertheless, patient symptoms of chest pain have to be evaluated very carefully and investigated accordingly. Simple chest X-ray and transthoracic echocardiogram would be sufficient in most cases [46]. Use of a CT chest could result in overreading lead perforation due to the presence of artifacts [47]. If there is any clinical suspicion for lead dislodgment, in most cases, lead revision would take care of the chest pain immediately.

2.2.3 Stress cardiomyopathy

Patients may develop stress cardiomyopathy/Takotsubo cardiomyopathy, in the postoperative period. Clinically, they may present with chest pain, shortness of breath, new onset arrhythmias, and positive troponins. Transthoracic echocardiogram will show apical ballooning and basal septal sparing [48]. Cardiac catheterization can confirm the absence of any major obstructive coronary artery disease. Even though the pathophysiology of the stress cardiomyopathy is evident, etiology of stress cardiomyopathy in the setting of pacemaker implantation is not very clear. This could be secondary to the stress events which led to the device implantation, medications used for sedation, pacing induced dyssynchrony, and/or due to the stress of the surgical procedure itself [49–51].

2.2.4 Diaphragmatic pacing

In a small percent of the population, it is possible that patients may have diaphragmatic pacing due to direct capture of the phrenic nerve [52]. This can be

interpreted as chest discomfort/hiccups, manifesting predominantly in certain position [53]. For a CRT device, the coronary sinus lead would be placed into the posterolateral or lateral branches which would abut the lateral wall of the left ventricle [54, 55]. The left phrenic nerve runs very close toward the lateral border of the left ventricle. Hence, this lead could be pacing the phrenic nerve and producing diaphragmatic contractions. Usually, during lead placement, high output pacing will be performed from the coronary sinus lead to rule out any phrenic nerve capture. However, secondary to displacement of the leads, it is possible that the leads can move and capture the phrenic nerve leading on to diaphragmatic contractions [56]. The right ventricular lead typically does not produce diaphragmatic pacing except in the following situations: (1) perforation of the right ventricle and migration of the lead inferiorly to produce direct capture of the diaphragm; (2) extreme RV dilation to the extent that the lateral border of the cardiac silhouette is situated near the right ventricular apex [57]. These situations require lead revision. On the other hand, the right-sided phrenic nerve travels along the lateral border of the right atrium, distant from the right atrial appendage, and can lead to diaphragmatic pacing if the right atrial lead becomes dislodged and captures the right phrenic nerve [58, 59].

2.3 Delayed onset chest pain

2.3.1 Surgical site pain

In most patients, surgical site chest pain would resolve within a week or so. However, some patients may have prolonged, local chest discomfort secondary to increased sensitivity. Other conditions including superficial device placement leading on to pressure on the skin (usually at the margin of the device), nerve entrapment, hematoma, allergic reactions, erosion, infection, etc., have to be ruled out [35–40]. Depending upon the etiology, we may have to open the pocket again and address the primary reason for the chest pain (**Figure 3**).

2.3.2 Delayed cardiac perforation

Delayed cardiac perforation secondary to CIED leads is uncommon when compared to acute perforation [60–62]. Patients will typically have symptoms of chest pain and the clinical presentation may not be as dramatic as an acute perforation. Hence a high degree of clinical suspicion needs to be maintained and early imaging including X-ray, echocardiogram, and, if needed, CT scan could be beneficial in these patients [62]. Further, device interrogation may show loss of capture, even at high output. Often these patients may need a multi-disciplinary approach including electrophysiologists and cardiothoracic surgeons [63].

2.3.3 Pacemaker-mediated angina

In patients who have underlying coronary artery disease, angina can be precipitated secondary to rapid pacing [64]. Usually, pacemakers are programmed to minimize right ventricular pacing. However, dual-chamber pacemakers tract the atrial electrical activity and the ventricular pacing follows. Hence, in patients with a high sinus rate or atrial tachycardia, the right ventricle could be paced at a higher rate, thereby resulting in demand ischemia [65, 66]. In the setting of underlying clinical or subclinical coronary artery disease, this in turn can lead to angina. This presents as a classical anginal form of chest pain. This can be identified by altering the pacemaker rate. Treatment typically involves reprogramming the device

Figure 3.
Cardiac implantable electronic device erosion.

to minimize right ventricular pacing and eventually taking care of the underlying coronary artery disease [67].

2.3.4 Post cardiac injury syndrome

Patients who underwent CRT-D implantation may have a 3–6 week delayed onset of chest pain; this is more pericardial in nature and similar to Dressler syndrome. The main differentiating factor from delayed pericardial effusion/pericardial tamponade is that there is no pericardial fluid in this situation [68]. The pathogenesis of post cardiac injury syndrome is immune mediated. Imazio et al. proposed diagnostic criteria for post cardiac injury syndrome with at least two out of five being required [69].

1. Unexplained fever

2. Pleuritic or pericardial chest pain

3. Pericardial rub on auscultation

4. New or worsening pericardial/pleural effusion on imaging

5. Elevated inflammatory markers including CRP

These patients respond very well to high-dose of aspirin, colchicine, or oral corticosteroids.

2.3.5 Painful left bundle branch block syndrome

Painful left bundle branch block (LBBB) syndrome is one of the uncommon delayed conditions seen with CIED placement [70]. Patients who have right ventricular pacemaker will have left bundle branch block morphology when pacing the

right ventricle. On electrocardiography, this can be differentiated from an acute LBBB using the six criteria outlined by Shvilkin et al. [70]: abrupt onset of chest pain coinciding with the development of LBBB; simultaneous resolution of symptoms with resolution of LBBB; normal 12-lead ECGs before and after LBBB; absence of myocardial ischemia during functional stress testing; normal left ventricular function and the absence of other abnormalities to explain symptoms; and low precordial S/T wave ratio consistent with new-onset LBBB (<1.8 in this series) and inferior QRS axis.

Most of the patients tolerate right ventricular pacing without any significant clinical features. However, a small population of patients may develop significant chest pain, independent of coronary artery disease [71, 72]. Although the underlying mechanism is unclear, several mechanisms have been postulated: (1) dyssynchronous ventricular contraction occur due to paradoxical septal movement during ventricular pacing, (2) there is abnormal activation of the neurons responsible for interception ventricular pacing, and (3) there is microvascular ischemia during ventricular pacing as noted by elevated concentration of lactic acid in the coronary sinus [73–75]. A careful history and observation of chest pain only during right ventricular pacing is the clue to the correct diagnosis. Treatment of these patients is very challenging but patients may respond very well to either CRT therapy or His bundle pacing [74, 76–78].

3. Conclusion

Almost all the patients that undergo CIED implantation will have some sort of chest pain dependent on the time of occurrence (**Table 1**). Most of the time this is secondary to surgical site pain. However, this could also be secondary to multiple reasons including life-threatening complications. Hence, early diagnosis and prompt treatment is warranted to minimize morbidity and mortality.

Delayed chest pain	**Post procedural chest pain (postoperative period, 1–2 days)**	**Immediate chest pain (perioperative period)**
Surgical site pain	Surgical site pain	Musculoskeletal
Delayed cardiac perforation	Pleuritic/pericardial involvement	Pneumothorax
Pacemaker-mediated angina	Stress cardiomyopathy	Mediastinal bleed
Post cardiac injury syndrome	Diaphragmatic pacing	Pericardial effusion/tamponade
Painful left bundle branch block syndrome		

Table 1.
Chest pain occurrence after cardiac implantable electronic device.

Conflict of interest

The authors declare no conflict of interest.

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